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TESTS OF METHODS OF PROTECTING WOODS AGAINST TERMITES OR WHITE ANTS.

A PROGRESS REPORT.

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INTRODUCTION.

Insects cause very large annual losses of forest products. A conservative estimate of loss, placed at but 2 per cent of the value of the yearly cut of forest products,[1] represents $45,000,000 annually. While much of the loss in both crude and finished forest products can be prevented by proper management, based on a knowledge of the life histories of the insects, nevertheless special preservative treatments are necessary to protect crude manufactured utilized products, such as lumber, dimension timbers (Pl. I, fig. 1), telephone and telegraph poles, mine props, and posts (Pl. I, fig. 6) as well as the more finished products, namely, interior woodwork (Pl. II, fig. 6), furniture (Pl. I, fig. 3; Pl. II, fig. 5), cabinet woods (Pl. II, figs. 1, 2), etc.

Saving forest products will help save our national forests. The various degrees of skilled labor, treatment handling, and change in ownership consequent in the transformation of forest trees into products greatly increases their value. Hence, wood preservation is of vital importance in the national program of forest conservation.

Termites or "white ants" are the insects which are especially destructive to untreated wood in any form, in both this country and the Tropics. Indeed, a large market for both crude and finished

[1] U. S. Dept. of Agriculture, Yearbook 1922, page 172.

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forest products could be found by American manufacturers in South America and in other tropical countries, provided a satisfactory "white-ant-proof" product could be furnished. After a preliminary survey of the extent of the damage throughout the country, a series of experiments were planned, which are outlined herein.

The following pages are a progress report on the results of these experiments conducted at Falls Church, Va., from 1912 to 1922, supplemented by data obtained by inspections of treated timbers made by the writer from 1909 to 1922, in service tests of telephone and telegraph companies. in cooperation with the United States Forest Service.

DESCRIPTION OF EXPERIMENTS.

On August 14, 1912, experiments were begun by the Forest Insect Investigations of the Bureau of Entomology in testing wood preservatives and insecticides to render wood or products of wood resistant to attack by wood-boring insects, especially by termites. Several objects were in view in these experiments.

Tests of the relative effectiveness of preservatives for timber to be set in or in contact with the ground were to be made. Preservatives, to be practicable for such use, should not only be insecticides but also disinfectants or fungicides. They should preferably be of low solubility in water and low volatility so that their poisonous effect will not be quickly destroyed by leaching (in wet situations) or by evaporation. Preservatives with heavy, nonvolatile, insoluble oils as constituents were known to be most effective. These requirements barred many chemicals that are otherwise very effective insecticides.

It was also desirable to determine the relative lengths of periods of effective service that could be expected of the superficial methods of treatment, such as brushing or dipping, compared with the more permanent methods of impregnation. In commercial enterprises, the type of treatment must necessarily be determined by cost and length of service.

When brush treatments are used, only high-grade antiseptic preservatives such as coal-tar creosote oils or carbolineums should be employed, since the cost of application of brush treatments is often high. The cost of any treatment should necessarily be more than offset by the longer service assured by the application. The several methods of application or impregnation of the preservative should be determined by the length of service required and the consequent expenditure warranted.

It was especially important to discover the most suitable preservatives for finished forest products, such as those used in interior finish, furniture, cabinet woods, etc., in order that American manufacturers might compete with foreigners for trade with the Tropics in "white-ant-proof" products. Such preservatives should not stain the wood, should not have a disagreeable odor, and should not "sweat" out in hot climates. It should be possible to paint or varnish over wood treated by them.

The proportions of poisonous chemicals necessary to add in the manufacture of wood-pulp products to prevent attack by termites were to be determined.

Tests were also to be made of untreated native and exotic timbers as to their relative resistance to attack by termites.

In the tests of preservatives for timber to be used in contact with the ground, stakes of southern yellow pine, 2 by 4 inches by 2 feet long, were placed in holes 3 feet apart and 1 foot deep, the holes being dug with a spade, 1 foot of the stake remaining above ground. The treatment of the stakes was done by the Forest Service at the Forest Products Laboratory, Madison, Wis., and a detailed physical description of each stake also was made. (Table 1.)

TABLE 1.—*Treatment and description of stakes treated for the Bureau of Entomology by the Forest Products Laboratory of the Forest Service, Madison, Wis.*

[Length of stake, 24 inches; length treated, about 17 inches.]

Treatment and stake No.	Species of pine.	Weight before treatment.	Weight after treatment.	Absorption.	Number of annual rings per inch.	Condition.	Dimensions of cross section.	Square inches of sapwood.
Open-tank, coal-tar creosote (shipment No. 154):		*Pounds.*	*Pounds.*	*Lbs.*			*Inches.*	
Stake 1	Shortleaf.	4.40	4.86	0.46	7	Sound	2.10×3.96	None.
2	do	3.95	4.57	.62	8	do	2.06×3.95	None.
3	do	4.13	5.35	1.22	10	do	1.94×4.06	None.
4	do	4.20	4.51	.31	5	do	1.94×4.08	None.
5	Longleaf.	4.70	6.29	1.59	15	do	2.12×4.18	2.5
6	Shortleaf.	4.18	4.54	.36	5	do	1.99×3.97	None.
7	Longleaf.	4.69	5.74	1.05	17	do	2.15×4.15	.2
8	Shortleaf.	4.63	5.15	.52	7	do	2.08×4.15	None.
9	Longleaf.	4.71	6.25	1.54	15	do	2.15×4.18	1.6
10	Shortleaf.	4.19	4.77	.58	10	do	2.08×3.82	None.
11	do	4.21	4.58	.37	5	do	1.92×4.15	None.
12	do	3.90	4.17	.27	9	do	1.86×3.96	1
Open-tank, wood creosote (shipment No. 126):								
Stake 13	do	4.86	5.17	.31	7	do	1.98×4.15	None.
14	do	3.35	3.69	.34	7	do	1.83×3.76	None.
15	do	3.65	3.88	.23	11	do	1.98×3.87	None.
16	do	3.79	4.00	.21	5	do	2.02×4.00	None.
17	do	4.23	4.48	.25	5	3 knots	2.04×4.00	None.
18	do	3.57	3.85	.28	7	1 knot	1.90×3.80	None.
19	do	3.98	4.29	.31	8	Slight trace of decay.	2.08×4.06	None.
20	do	5.71	7.32	1.61	13	Small knot.	2.26×4.17	None.
21	Longleaf.	3.65	3.87	.22	7	Sound	2.09×3.93	None.
22	Shortleaf.	3.95	4.37	.42	5	2 knots	2.15×4.13	None.
23	do	3.37	3.67	.30	5	Sound	1.92×3.78	None.
24	do	3.58	3.94	.36	5	do	1.90×3.82	None.
Charred:								
Stake 25	do	3.87	4.08	.21	8	1 knot	2.17×4.30	None.
26	do	3.53	3.67	.14	8	Sound	2.14×3.78	.4
27	do	3.64	3.84	.20	6	do	2.10×3.31	None.
28	Longleaf.	5.13	5.31	.18	18	Checked	2.21×4.25	None.
29	Shortleaf.	3.27	3.47	.20	5	1 knot	1.94×3.63	None.
30	Longleaf.	4.47	4.72	.25	19	Sound	2.00×4.02	.9
31	Shortleaf.	3.81	3.98	.17	6	do	2.06×3.80	None.
32	do	3.29	3.46	.17	7	Large knot.	1.94×3.92	None.
33	do	4.56	4.81	.25	7	Sound	2.08×4.16	None.
34	do	3.52	3.69	.17	7	Large knot.	2.06×4.04	None.
35	do	3.70	3.85	.15	5	Sound	2.00×3.85	None.
36	Longleaf.	5.58	5.93	.35	18	do	2.25×4.25	None.
Dipping, coal-tar creosote (shipment No. 154):								
Stake 37	Shortleaf.	4.43	4.49	.06	6	do	2.06×4.01	None.
38	do	3.33	3.40	.07	5	do	2.11×3.90	None.
39	Longleaf.	5.75	5.96	.21	15	do	2.42×4.11	1.3
40	Shortleaf.	3.73	3.78	.05	6	Small knot.	2.15×3.77	None.
41	Longleaf.	5.45	5.60	.15	13	Sound	2.20×4.18	3.8
42	do	4.61	4.68	.07	12	do	2.08×3.75	None.
43	Shortleaf.	3.83	3.88	.05	5	do	2.20×3.90	None.
44	do	4.21	4.27	.06	6	do	1.99×3.80	None.
45	do	4.14	4.21	.07	7	do	2.15×4.25	None.
46	do	3.77	3.82	.05	6	do	1.98×4.02	None.
47	do	3.66	3.73	.07	7	do	1.98×4.05	None.
48	Longleaf.	5.15	5.35	.20	16	do	2.20×4.17	None.

TABLE 1.—*Treatment and description of stakes, etc.*—Continued.

Treatment and stake No.	Species of pine.	Weight before treatment.	Weight after treatment.	Absorption.	Number of annual rings per inch.	Condition.	Dimensions of cross section.	Square inches of sapwood.
Brush treatment, 3 coats coal-tar creosote (shipment No. 154):								
		Pounds.	*Pounds.* I II III	*Lbs.*			*Inches.*	
Stake 49	Longleaf.	4.10	4.16 4.17 4.17	0.07	12	1 knot	1.95×3.90	None.
50	...do	5.99	6.03 6.04 6.04	.05	16	Sound	2.17×4.20	None.
51	...do	4.49	4.56 4.57 4.58	.09	12	...do	2.06×3.82	1
52	Shortleaf.	3.93	3.98 3.99 4.00	.07	5	2 knots	2.20×4.16	None.
53	...do	3.79	3.84 3.84 3.84	.05	7	Sound	2.05×3.90	None.
54	...do	4.31	4.37 4.38 4.39	.08	6	2 knots	2.08×4.00	None.
55	...do	3.37	3.44 3.45 3.46	.09	5	Sound	1.98×4.00	None.
56	...do	3.99	4.02 4.02 4.02	.03	7	...do	1.95×4.10	None.
57	...do	3.56	3.61 3.61 3.60	.04	7	...do	1.90×3.95	None.
58	...do	3.62	3.68 3.69 3.69	.07	6	1 knot	2.00×3.85	None.
59	Longleaf.	3.94	4.01 4.03 4.04	.10	15	Sound	2.10×3.80	0.4
60	Shortleaf.	3.49	3.55 3.56 3.56	.07	6	...do	1.94×3.82	.5
Dipping, wood creosote (shipment No. 126):								
Stake 61	Longleaf.	5.22	5.33	.11	17	Checked	2.16×4.25	None.
62	...do	4.37	4.46	.09	8	Sound	2.08×3.90	None.
63	...do	5.13	5.35	.22	9	...do	2.10×4.18	3.2
64	Shortleaf.	4.27	4.36	.09	7	...do	2.00×4.10	None.
65	...do	4.23	4.31	.08	6	1 knot	2.12×3.98	None.
66	Longleaf.	5.16	5.23	.07	16	Sound	2.02×4.10	None.
67	...do	4.01	4.10	.09	11	1 knot	1.98×3.90	.4
68	...do	6.03	6.11	.08	16	Sound	2.25×4.18	None.
69	...do	5.23	5.36	.13	16	Slight check	2.23×4.25	None.
70[1]	Shortleaf.	3.86	3.94	.08	5	Sound	2.00×3.90	None.
71	...do	4.21	4.28	.07	7	1 knot	2.00×4.17	None.
72	Longleaf.	4.08	4.16	.08	8	Sound	2.00×4.00	None.
Brush, wood creosote (shipment No. 126), three coats:			I II III					
Stake 73	...do	5.49	5.58 5.60 5.61	.12	13	...do	2.08×4.20	2
74	...do	5.68	5.79 5.82 5.84	.16	13	2 small knots.	2.23×4.15	2
75	Shortleaf.	3.71	3.78 3.79 3.80	.09	6	Sound	1.93×4.10	None.
76	Longleaf.	5.88	5.98 6.00 6.02	.14	13	...do	2.40×4.12	.5
77	Shortleaf.	3.93	3.99 4.00 4.00	.07	5	Large knot.	2.00×3.92	None.
78	Longleaf.	4.63	4.71 4.74 4.75	.12	11	Sound	2.08×4.05	.2
79	...do	4.16	4.24[2] 4.27 4.26	.10	7	...do	2.10×4.08	None.
80	Shortleaf.	4.63	4.70 4.72 4.73	.10	6	...do	2.11×4.18	1
81	Longleaf.	6.16	6.26 6.29 6.31	.15	11	Large knot.	2.35×4.23	.3
82	...do	5.11	5.20 5.22 5.23	.12	18	Sound	2.10×4.10	.6
83	...do	4.05	4.11 4.13 4.13	.08	8	2 small knots.	1.95×4.09	None.
84	Shortleaf.	3.72	3.78 3.80 3.80	.08	5	...do	2.05×4.13	None.
Brush, carbolineum, three coats:								
Stake 85	...do	4.47	4.53 4.54 4.54	.07	7	Sound	2.00×4.53	None.
86	...do	4.39	4.47 4.50 4.50	.11	7	...do	1.96×4.23	None.
87	...do	4.26	4.34 4.35 4.36	.10	7	Small knot.	1.95×4.23	None.
88	...do	3.95	4.01 4.03[2] 4.02	.07	4	Sound	1.95×3.85	None.
89	...do	4.46	4.52[2] 4.53 4.52	.06	7	...do	2.00×4.52	None.
90	...do	3.53	3.59 3.60 3.60	.07	7	...do	2.00×4.10	None.
91	...do	3.54	3.63 3.63 3.63	.09	8	...do	2.07×4.15	None.
92	...do	3.86	3.93[2] 3.95 3.94	.08	4	...do	1.99×3.87	None.
93	...do	4.27	4.35 4.37 4.37	.10	6	...do	2.02×4.20	None.
94	...do	4.44	4.52 4.55 4.55	.11	6	...do	2.00×4.20	None.
95	...do	3.96	4.03[2] 4.05 4.04	.08	6	...do	2.10×4.20	None.
96	...do	4.40	4.44[2] 4.47 4.46	.06	5	...do	2.00×3.85	None.

[1] Attacked by termites.

[2] The apparent discrepancies in Table 1 between the weights of the specimens before and after brush treatments with creosote and similar oils are very likely due to loss of moisture from the wood during the time which elapsed between coats of preservatives. It is quite possible that the wood was brought into the laboratory from outdoors in order to apply the treatments. The laboratory conditions were probably drier than outdoor conditions and the tendency of the wood to lose moisture would be rather marked. It would be quite possible for the wood to lose an amount of moisture greater than the weight of creosote applied in any one brushing.

TABLE 1.—*Treatment and description of stakes, etc.*—Continued.

Treatment and stake No.	Species of pine.	Weight before treatment.	Weight after treatment.	Absorption.	Number of annual rings per inch.	Condition.	Dimensions of cross section.	Square inches of sapwood.
Dipping, carbolineum:		*Pounds.*	*Pounds.*	*Lbs.*			*Inches.*	
Stake 97	Shortleaf.	3.57	3.64	0.07	7	Sound	1.97×4.25	None.
98	do	4.22	4.28	.06	9	1 knot	1.94×4.20	None.
99	do	4.10	4.18	.08	6	Sound	2.08×4.27	None.
100	do	3.84	3.91	.07	7	do	2.07×4.23	None.
101	do	4.04	4.12	.08	5	do	2.00×4.12	None.
102	do	3.93	3.99	.06	4	Large knot.	1.98×3.73	None.
103	do	3.79	3.87	.08	7	Sound	2.04×4.00	None.
104	do	3.64	3.73	.09	4	do	2.07×3.90	None.
105	do	3.39	3.45	.06	5	do	1.90×3.75	None.
106	do	3.47	3.56	.09	5	do	2.06×3.88	None.
107	do	4.07	4.18	.11	6	Large knot.	1.95×3.93	None.
108	do	3.43	3.53	.10	4	do	2.00×3.75	None.

Stakes 1 to 12, inclusive, were treated by the open-tank process with coal-tar creosote, Laboratory Shipment No. 154. The preservative was first heated to from 212° to 220° F., whereupon the specimens were immersed, the charge being held at the foregoing temperature for 1½ hours. The charge was then allowed to cool, after which the specimens were removed and weighed. This process was repeated, the specimens being finally allowed to stand in the preservative overnight. The average absorption at the completion of the treatment was approximately 8 pounds per cubic foot.

Stakes 13 to 24, inclusive, were treated by the open-tank process with wood creosote obtained from a turpentine company, Laboratory Shipment No. 126. The specimens were immersed in the preservative at a temperature of 180° F. for 1½ hours, after which the charge was permitted to cool overnight.

Stakes 25 to 36, inclusive, were charred by permitting them to burn for approximately five minutes in an open fire.

Stakes 37 to 48, inclusive, were merely dipped in coal-tar creosote, Laboratory Shipment No. 154, at a temperature of 216° F.

Stakes 49 to 60, inclusive, were brush-treated with coal-tar creosote, Laboratory Shipment No. 154. The temperature of the preservative was 216° F., and three coats were applied at intervals of 24 hours.

Stakes 61 to 72, inclusive, were merely dipped in wood creosote secured from a turpentine company, Laboratory Shipment No. 126, at a temperature of 180° F.

Stakes 73 to 84, inclusive, were brush-treated with wood creosote from a turpentine company, Laboratory Shipment No. 126, three coats being given at a temperature of 180° F. at intervals of 24 hours.

Stakes 85 to 96, inclusive, were brush-treated with a high-grade carbolineum, three coats of the preservative being applied at a temperature of 170° F. at intervals of 24 hours.

Stakes 97 to 108, inclusive, were merely dipped in a high-grade carbolineum at a temperature of 170° F.

Thus 108 stakes were treated in all, numbered from 1 to 108.

One hundred and eight untreated check stakes were also set in the ground with these treated stakes, 54 entirely of heartwood (numbered from 194 to 247), the others with some sapwood; stakes treated by each method or chemical were so arranged that there was an even distribution of treatments throughout the test area. (See fig. 1 for arrangement of stakes; also Pl. I, fig. 5.)

In October, 1916, it was necessary, on account of change in location of laboratory, to move all the treated woods to a new plot near by.

The locality in Virginia where these stakes were set is one in which termite colonies of several species of Reticulitermes were abundant, *R. flavipes* Kol. being the most common termite. No. attempt was made to hasten normal attack by termites, hence the

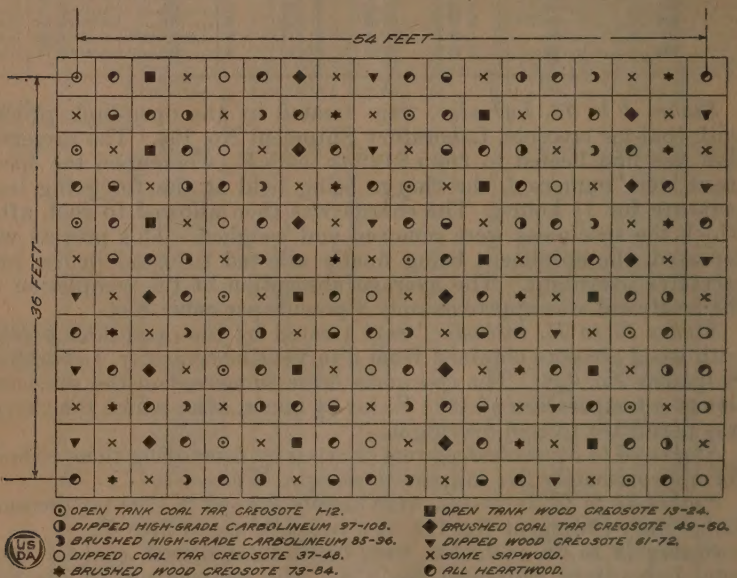


FIG. 1.—Arrangement of experimental stakes at Falls Church, Va.

test is essentially a service test. Some of the untreated stakes had become infested by March, 1913; after one year 57 and after 25 months 95 of the first lot of untreated stakes were attacked by termites.

On May 21, 1913, additional 2 by 4 inch southern yellow-pine stakes were set in the ground, which were treated by more permanent methods of impregnation by a commercial wood-preserving company, using coal-tar creosote oils and wood creosote. Analyses of these coal-tar creosote oils were made by the manufacturer, whereas the wood creosote was analyzed by the United States Bureau of Chemistry, with the results shown in Table 2.

In addition to being attacked by termites both untreated check and treated stakes were also attacked by wood-boring beetles, espe-

cially Eucnemidae,[2] as well as fungi. The tips of many treated stakes were badly checked at the last examination in 1922.

TABLE 2.—*Chemical analyses of oils B or No. 1[1] and A or No. 2[2] made by the manufacturer.*

	1, B.	2, A.
Standard distillation (totals by weight):		
170°	0	0
200°	0.3	1.1
210°	8.0	8.1
235°	39.2	46.7
315°	42.6	32.5
355°	9.2	6.4
Specific gravity at 15.5°	1.047	1.044
Tar acids.....per cent.	8	23
Dry naphthalene.....do....	30.08	25.00

[1] Fraction 210°-235° C. solid at laboratory temperature.
[2] All fractions liquid excepting 315°-355° (which contained anthracene).

NOTE.—Dry naphthalene represents solid matter at 15° C., but if cooled to zero sufficient solid matter would be obtained to bring it at least to 40 per cent. The percentage of solids in oil can be increased by lowering the temperature, and a 40 per cent naphthalene oil had been desired in the case of No. 1.
Oil No. 1 (B) was intended for an oil high in naphthalene with a normal tar-acid content, whereas oil No. 2 (A) was intended for an oil high in tar acids with normal naphthalene content.

Pine-tar oil; i. e., wood creosote (Misc. Div. No. 15787):
Appearance, Dark brown, slightly viscous liquid.
Odor, Pine-tarry and empyreumatic.

Specific gravity 29° C	1.0285.
Pyridines	Traces only.
Water and pyroligneous acid	Traces only.
Mineral oils	None.
Ash	0.4 per cent by weight.
Volatile oils excluding phenolic bodies (turpentine, pine oil, and apparently traces of rosin spirit)	12.8 per cent by weight.
Phenolic bodies (guaiacol, etc., volatile tar acids from wood tar, creosote, essentially free from coal-tar acids)	11.9 per cent by weight.
Bodies not distilling below 360° C. (pitch, very heavy oils, etc.)	10 per cent approximately.
Rosin oil and other heavy pine-tar oils (by diff.)	64.9 per cent
Behavior on distillation:	
100° C. to 155° C	1.5 per cent by volume.
155° C. to 180° C	4 per cent by volume.
180° C. to 210° C	16 per cent by volume.
210° C. to 230° C	11 per cent by volume.
230° C. to 270° C	16.5 per cent by volume.
270° C. to 360° C	42 per cent by volume.
Pitch, loss, etc. (by diff.)	9 per cent by volume.

Consists essentially of the so-called heavy oil obtained in pine-tar distillation.

Twelve stakes were impregnated by the full-cell pressure process with creosote oil (Oil B or No. 1, see analysis, Table 2, p. 7) containing a high percentage of naphthalene; 12 stakes were impregnated with a creosote oil (Oil A or No. 2, see analysis, Table 2, p. 7) containing a high percentage of tar acids; 12 stakes were impregnated with wood creosote (see analysis, Table 2, p. 7, No. 15787); 12 stakes were impregnated by the Rueping (empty-cell) pressure process with creosote Oil A or No. 2; 12 were impregnated with creosote Oil B or No. 1, and 12 impregnated with wood creosote. There were 72 treated stakes in all. In addition, 12 stakes were treated to refusal

[2] Especially *Dromaeolus striatus* Lec.

with Oil A, No. 2. Stakes under these treatments were numbered from 109 to 193, and received the treatments shown in Table 3.

TABLE 3.—*Oils and processes used in impregnating Stakes 109 to 193.*

Oil A.		Oil B.		Wood creosote.		Oil A.
Full-cell.	Rueping.	Full-cell.	Rueping.	Full-cell.	Rueping.	Special.
Stake.	*Stake.*	*Stake.*	*Stake.*	*Stake.*	*Stake.*	*Stake.*
117	168	112	115	110	134	109
118	169	113	119	131	150	114
121	171	126	120	132	151	122
123	172	127	124	133	152	148
125	173	128	116	147	156	174
144	177	130	138	153	157	175
149	178	135	139	155	158	181
176	179	136	140	167	159	183
182	180	137	142	170	160	186
187	184	143	146	190	162	189
188	185	145	161	192	163	.....
111	191	166	164	193	165	.....

Treatment marked "Special" treated with oil to refusal.

Stakes 129, 141, and 154 were missing.

With these treated stakes were placed 22 untreated check stakes. (See fig. 2 for arrangement of stakes.)

Other treated stakes have since been added to this test at irregular intervals.

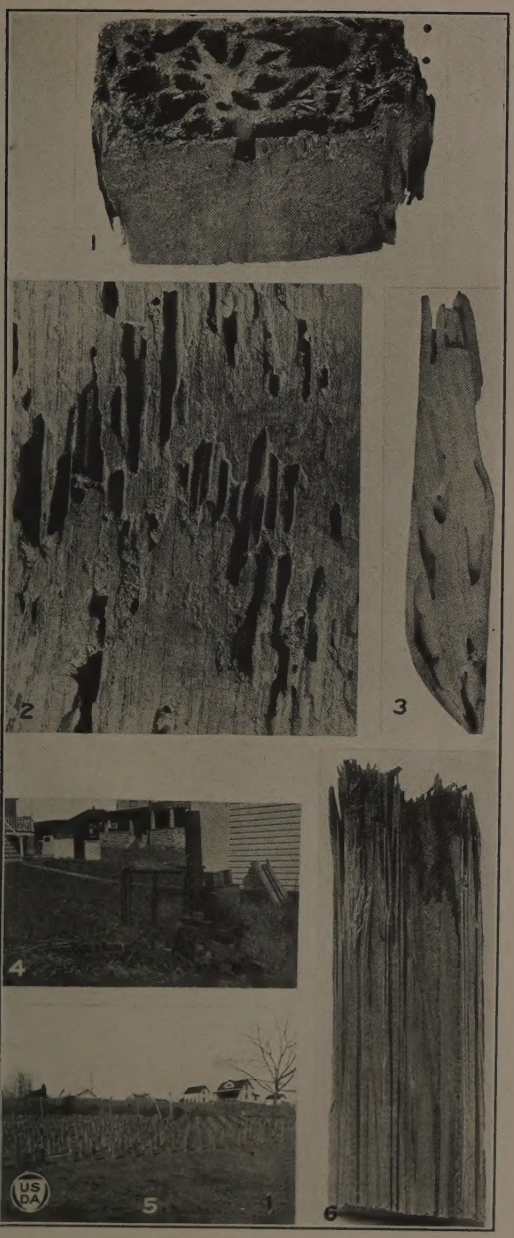
Coal-tar creosote oils containing varying percentages (high and low) of naphthalene and tar acids were included in the test treatments, since it was formerly considered that a high percentage of naphthalene in coal-tar creosote oils was more effective against marine borers and that a high percentage of tar acids was more effective as an antiseptic in preventing fungous decay.

Some of the objections to coal-tar creosote as a wood preservative are discoloration, odor, and smarting to eyes and touch, "sweating" in hot climates, soiling clothes, and corroding rubber insulation; that is, when conduits are impregnated with creosote, the creosote is said to be injurious to the rubber insulation on cables. Wood treated with creosote can not be painted or finished after treatment.

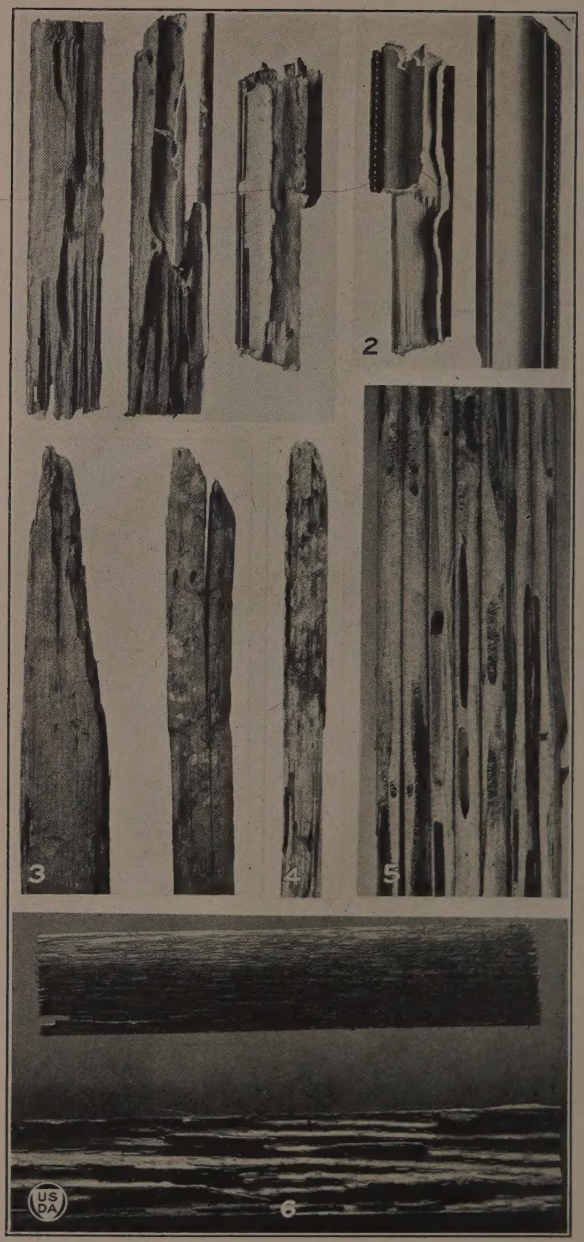
Many of the objections can be avoided by proper treatment and regulating the amount of creosote held in the wood by the "empty-cell" or "open-tank" impregnation treatments. Impregnation with coal-tar creosote is by far the most effective treatment for timber to be placed in or in contact with the ground. Attack by termites to a telephone pole line in Virginia is very slight (usually through season checks), after 25 years' service. By adding pigment to creosote, as is done in the preservative treatment given shingles, a painted effect can be obtained which does away with the brown discoloration,

DESCRIPTION OF PLATE I.

EXPERIMENTAL WORK WITH WOOD PRESERVATIVES AND DAMAGE TO RESISTANT REDWOOD AND WOODWORK IN BUILDINGS BY TERMITES: 1, Section of woodwork in building damaged by *Cryptotermes brevis* at San Jose, Costa Rica. 2, An ineffective method of wood treatment. Experimental ash block steamed 10 hours at 28 pounds pressure, after 6 months' tests buried in the ground with logs infested by Reticulitermes in Virginia. 3, Rocker of rocking chair damaged by *C. brevis*, Key West, Fla. 4, Homemade, crude "open tank" plant at eastern field station, Falls Church, Va. 5, View of a portion of the treated experimental stakes at Falls Church, Va., March, 1917. 6, One of several fence posts of redwood (*Sequoia sempervirens*) (heartwood) damaged by the termite *Reticulitermes humilis* var. *hoferi* from Sabino Canyon, Santa Catalina Mountains, Ariz.



WOOD DAMAGED BY TERMITES AND EXPERIMENTAL WORK WITH WOOD PRESERVATIVES.



RESISTANT REDWOOD DAMAGED BY NATIVE TERMITES, AND OTHER DAMAGE TO WOOD BY TERMITES.

and the substance apparently dries more quickly. Tests have proved that the addition of pigments, notably green, does not affect the resistant qualities of the treated wood.

The quantity of pigment (green) added to the creosote oils used in the experiments was 1 pound of pigment to 1 gallon of creosote. It is believed that satisfactory physical properties can be obtained by reducing the amount of pigment, if the pleasing stain is not of primary importance. The wood which was treated was yellow pine and was more than half seasoned. Where the mixture was applied by means of dipping, coal-tar creosote and pigment alone were used; but where creosote and pigment were applied with a brush the mixture was slightly thinned with linseed oil, so as to encourage drying and make the application easier.

According to the Forest Products Laboratory, red and brown pigments are less expensive than green; furthermore, a smaller amount of red or brown pigment is necessary to obtain a satisfactorily colored creosote than in the case of green. Red and brown pigments can be used by the open-tank method or pressure method, whereas

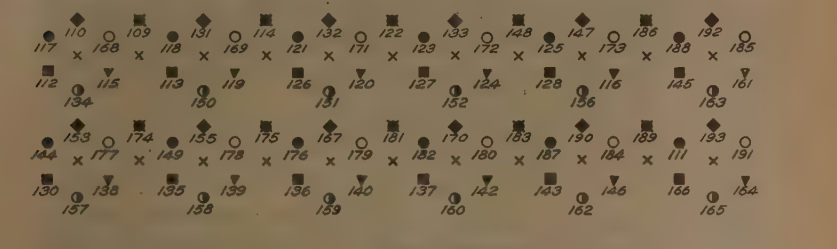


FIG. 2.—Arrangement of stakes treated by the cylinder pressure process at Falls Church, Va.

brushing or dipping must be used with green. The proportions are 8 to 12 ounces of pigment (ground in oil) mixed with an equal bulk of linseed oil for each gallon of creosote.

TREATMENTS FOR TIMBER TO BE SET IN THE GROUND.

SUPERFICIAL TREATMENTS.

The superficial brushing and dipping methods are temporarily effective in preventing attack by insects to timber and crude forest products; results of tests and examinations of service test telephone pole lines indicate that the treated wood set in the ground usually resists attack by wood-boring insects from 2 to 8 years, depending upon the chemical, the thoroughness of the treatment, the character

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DESCRIPTION OF PLATE II.

RESISTANT REDWOOD DAMAGED BY NATIVE TERMITES AND OTHER DAMAGE TO WOOD BY TERMITES: 1, Picture molding infested and ruined by *Cryptotermes brevis* in the old Colonial Hotel, Nassau, N. P., Bahamas, 1921. View showing damage exposed. 2, Same, showing how interior is eaten out, leaving hollow shell but with outer layers intact. 3, Permanent redwood stakes to support grapevines in Merced County, Calif., vineyards damaged by the termite *Reticulitermes hesperus*, which also injures the young vines. Side view. 4, Same, edge view. 5, Bureau drawer injured by the termite *C. brevis*, Key West, Fla. 6, Oak flooring damaged by Reticulitermes in the eastern United States; note how damage is hidden (upper surface).

of the site, and the geographical situation. Coal-tar creosote and carbolineums have been found to be the most effective preservatives. Several coats of coal-tar creosote brushed on timber will add from 2 to 5 years to its life. In the tests at Falls Church, Va., brushing with coal-tar creosote (three coats applied hot) was more effective in preventing attack by termites than was dipping in the hot preservative. As has been stated, much depends upon the preservative.

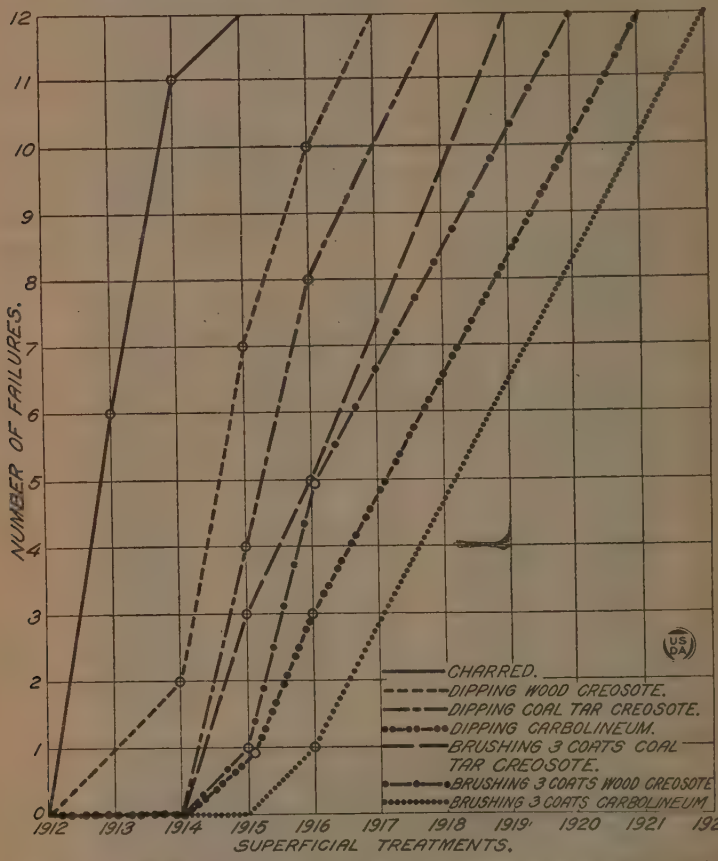

FIG. 3.—Comparison of the relative resistance to attack by termites of chemical wood preservatives and methods of treatment, Falls Church, Va., 1912–1922.

Heavy or thick coatings of tar for the bases of poles or posts are not effective and are valueless as preservative treatments. Many patented or proprietary preservatives or methods failed after short periods of test and are not referred to, except in a few cases.

IMPREGNATION TREATMENTS.

Methods by which the preservative is more thoroughly impregnated into the wood more permanently protect wood from insect attack. These methods of course are more expensive. Inspections of

treated timber by the writer indicate that the "open-tank" method of impregnation with coal-tar creosote renders wood resistant to attack by wood-boring insects for at least 15 years. Treating of wood by this method can be done with homemade apparatus (Pl. I, fig. 4), using unskilled labor. The timber should be well seasoned before impregnation, however, and the treating should be very carefully done; a uniform penetration should be secured, sufficiently deep to allow for season checking; this is especially necessary if the treated timber is to be set in warm climates.

Impregnation treatments by the more technical pressure processes are the most effective, as well as the most costly, but the results usually justify the extra cost. Inspections of treated timber by the writer indicate that impregnation by the full-cell pressure process will render wood resistant for at least 25 years.

The results of the tests of the comparative effectiveness of the superficial methods of treating timber in protecting it against attack by termites are given in Figure 3 and Table 4, while the results of the impregnation treatments are given in Table 5.

TABLE 4.—*Results of tests of the relative effectiveness in preventing attack by termites of miscellaneous superficial chemical preservative treatments for crude or finished forest products.*

Preservative.	Method of application.	Species of wood treated.	Effectiveness.
Liquid M, a volatile yellow fluid, 2 per cent solution.	Both brushing, 2 coats applied hot, and dipping.	Yellow pine	Failure after 4 months.
"Ebonizing," chromic acid and aniline oil.	Brushing, applied hot.	Ash and yellow pine.	Failure after 5 months.
Liquid S, a yellowish oily liquid with a strong varnish odor.	Both brushing, 2 coats (one week between coats), and dipping.	Yellow pine	Failure after 6 months.
Preservative T, a preservative paint	Both brushing and soaking.	Ash	Failure after 1 year.[1]
Oil S, a creosote oil made from coniferous wood.	Brushing	Chestnut	Effective for less than 5 years.[1]
Oil C, a very light gravity brown oil, containing much tar, acids, and water.	do	do	Do.[1]

[1] Period when first examination was made after setting.

TABLE 5.—*Results of tests of methods of impregnating woods with preservatives to prevent attack by termites, 1913 to 1922.*

Treatment.	Results.
Full-cell pressure process:	
Commercial wood creosote (No. 126), tested with yellow pine	No failures.
Commercial coal-tar creosote (No. 154), tested with yellow pine	Do.
Coal-tar creosote oil A, tested with yellow pine	Do.
Coal-tar creosote oil B, tested with yellow pine	Do.
Steaming for various periods under different pressures, tested with ash	Failure after 6 months.[1]
Empty-cell pressure process, using yellow pine for test:	
Commercial wood creosote (No. 126)	5 failures out of 12 in 1922.
Commercial coal-tar creosote (No. 154)	No failures.
Coal-tar creosote oil A	Do.
Coal-tar creosote oil B	Do.
Open-tank process, using yellow pine for test:	
Commercial wood creosote (No. 126)	1 failure in 1916; 5 failures out of 12 in 1922.
Commercial coal-tar creosote (No. 154)	No failures.
Coal-tar creosote oil A	Do.
Coal-tar creosote oil B	Do.
Boiled in iron sulphate solution for 2 hours, then plunged in copper sulphate solution and left for 2 hours.	Failure after 5 years.

[1] Period when first examined after placed in test.

TABLE 5.—*Results of tests of methods of impregnating woods, etc.*—Continued.

Treatment.	Results.
Open-tank process, using yellow pine for test—Continued.	
Boiled 1½ hours in a stock solution of poisoned kerosene emulsion (1 gallon water, 2 gallons kerosene oil, ½ pound naphtha soap, ½ pound sodium arsenate)—	
Allowed to cool in mixture	Failure after 6 years.
Cooled and dipped in carbolineum	Do.
Boiled 1 hour in 2 gallons of creosote emulsion poisoned with ½ pound sodium arsenate—	
Allowed to cool in the mixture	Do.
Left in kerosene oil for 1 hour after treatment	Do.
Left in coal-tar creosote for 1 hour after treatment	Do.
Boiled 1 hour in 1 gallon kerosene oil, 1 gallon coal-tar creosote, ½ pound naphtha soap, ½ pound sodium arsenate, 1 gallon water; allowed to stand 1 hour in carbolineum.	Not attacked by termites after 6 years' test.
Boiled ½ hour in a 5 per cent solution of sodium arsenate and left soaking for 2 days, then boiled for 1 hour in sodium arsenate and soaked for 1 hour in carbolineum.	Do.
Boiling:	
Paraffin wax, tested with both coniferous and hardwood species	Failure after 6 months.
Saccharine solution and arsenic, tested with maple and ash	Failure after 1½ years.
Chlorinated naphthalene, tested with both coniferous and hardwood species	Not attacked after 3 years.
Impregnation and baking:	
Formaldehyde and carbolic acid combination, tested with pine	Failure after 8 years.
Encysting:	
Naphthalene, paraffin, and silica, tested with ash	Failure after 7 years (sweat badly).

OTHER TREATMENTS.

There are also simpler though less effective methods other than treatment with chemicals to prolong the life of timber, such as setting in stone, charring, steaming (Pl. I, fig. 2), etc. By burning (i. e., for poles, posts, etc.) in an open fire till the outer layers are charred, wood is rendered more resistant to insect attack. Charred wood will not be damaged by termites till one year after being set in the ground, and not seriously damaged till after at least two years of service. However, charring should not be depended upon to preserve wood, although it is quite possible that it renders the wood more resistant to insect attack. A more effective method is to dip the butts of fence posts for a few minutes in crude oil and then char them.

TREATMENTS FOR WOOD PRODUCTS NOT TO BE SET IN CONTACT WITH THE GROUND OR IN WET SITUATIONS.

Finishing products—such as cabinet woods, furniture, and the interior woodwork in buildings—as well as unfinished products stored to season before finishing, require treatment different from that given to crude products to be set in the ground. While the preservatives with which such woods are to be treated should generally be antiseptic, they should never be insoluble in water, except in the case of flooring or other woods near or in contact with the ground. These preservatives in most cases should not "sweat out" or stain the wood. Impregnation with 2 to 5 per cent solutions of zinc chlorid by the Bethel full-cell process or "Burnettizing" is in most common practice; only the woods which treat with the greatest difficulty require 6 per cent solutions.

Timber impregnated with sodium fluorid is apparently as resistant to attack by termites as timber impregnated with zinc chlorid (standard specification one-half pound of dry salt per cubic foot). Sodium fluorid, however, is much more expensive than zinc chlorid.

Another method is the "Kyanizing" process, consisting of a steeping treatment with a 1 per cent solution of bichlorid of mercury; this chemical, however, is extremely poisonous (see p. 15), which may greatly restrict its use. All of the above treatments are effective for flooring, interior woodwork, other fixtures, or furniture.

Impregnation with chlorinated naphthalene is an effective treatment for valuable cabinet woods or expensive furniture; it is also a moisture-retarding treatment.

Chlorinated naphthalene is a crystalline wax with a melting point of about 196° F. It is made in several grades varying in specific gravity, melting point, and other characteristics, according to the extent to which the chlorination process is carried.

The chlorinated naphthalene used in these tests is a mixture of various chlorinations as well as free naphthalene, with a large preponderance, however, of tri chlor naphthalene.

This material is usually referred to as tri chlor naphthalene and, as compared with other chemicals, it is really comparable to a technical product having naphthalene, mono chloro naphthalene, di chlor naphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190° and 210° F. This is the specification under which it is sold.

The grade used in these tests, as identified by the melting point stated, sells at 36 cents per pound in carload lots; a less refined grade can be purchased for 20 cents per pound in the same quantity.

The samples of wood for test were treated as follows: Blocks of the wood 6 by 6 inches by ½ inch were placed, without previous drying, in an open pot of the chlorinated naphthalene at a temperature of from 220° to 240° F. and allowed to remain fully covered by the molten wax for 15 minutes. The blocks of wood were then removed and wiped off with a cloth. The treated wood can be stained, shellacked, and varnished. The resultant color will be somewhat darker than the color of untreated wood, and care must be exercised in cleaning the surface thoroughly to insure proper adherence of shellac or varnish.

The different woods varied greatly in the amount of wax taken up in the above treatment. Furthermore, the amount of wax taken up will vary according to the size and condition of the wood treated. The blocks carried approximately 5 per cent of wax, or at the rate of from 2 to 3 ounces of wax per board foot. At the above price for the impregnating material, the treatment would be rather expensive and possibly prohibitive for ordinary use, such as flooring.

The treatment also renders the wood moisture-retarding to a marked degree, and its cost is sometimes justified by this double effect.

In the tests of untreated woods and woods that were treated with preservatives for use in finished forest products, such as furniture, cabinets, etc., experimental blocks of wood from various species of both coniferous and broad-leaved trees were buried in the ground with logs heavily infested with termites (*Reticulitermes* spp.) at Falls Church, Va. These blocks were 6 inches square by one-half

inch thick. These experiments were begun on April 10, 1913. The blocks were examined twice each year. Similar test blocks were sent to the Tropics (Brazil, Ecuador, and Cuba) for test under more severe conditions.

In the experiments untreated woods and certain treated woods failed after 6 months' exposure to the attacks of termites. This is a very severe test for finished forest products, since in use they would not be placed in the ground.

After a three-year test, it was found that tropical woods, such as teak, mahogany, and peroba, while resistant to termite attack, are not wholly immune; they stand in the order named in comparative immunity.

The woods from the northeastern part of the United States, untreated, are very susceptible to attack. Treatment with paraffin accomplished nothing, as the woods were readily attacked and also suffered decay. Treated with chlorinated naphthalene, the woods from the Northeastern States were attacked but little, comparing favorably with untreated teak and mahogany. (Table 5.)

Many preservative treatments for furniture and cabinet woods are objectionable, since they discolor or will not permit fine finishes. In these cases the hidden, interior parts may be so treated and then be covered by veneers of cabinet woods which are resistant to attack by termites.

TERMITE-RESISTANT WOODS.

The results of tests conducted from 1913 to 1922 at Falls Church, Va., and inspections in the field by the writer, appear to warrant the statement that there is no species of tree the wood of which is absolutely immune to attack by termites. Nevertheless, the heartwood of certain trees is very resistant to attack by termites (*Reticulitermes* sp.).

Among the most resistant woods which were tested are teak (*Tectona grandis*) and sâl (*Shorea robusta*) of India; cypress-pine (*Callitris robusta*) and camphor wood (*Cinnamomum camphora*) of the Orient; greenheart (*Nectandra rodiaei*) of South America; redwood (*Sequoia sempervirens*) (Pl. II, figs. 3, 4); western red cedar or giant arborvitae (*Thuja plicata*);[2] incense cedar (*Libocedrus decurrens*); Port Orford cedar (*Chamaecyparis lawsoniana*); yellow cypress (*Chamaecyparis nootkatensis*), and species of Junipers (*Juniperus* spp.) of the United States.

Certain other South American and Philippine woods were tested on too small a scale to warrent definite statements as to their relative resistance to attack by termites. Many of these woods may prove to be very resistant. Further tests should be made.

It is the presence of certain chemical constituents of the wood which renders it resistant. Stakes of longleaf pine (*Pinus palustris*) of Texas, cut from butt logs containing a large resin content (locally called "fatwood" or "lightwood") remained unattacked by termites after being set in the ground exposed to their attacks from 1913 to 1922, whereas normal pine wood is very susceptible to attack by termites.

[2] Red cedar poles are seriously damaged by termites (Kalotermes) in California.

Certain of the woods named would make very suitable veneers to overlay and conceal chemically treated interior and hidden parts of furniture, which could be made of any of the cheaper woods of the United States. Impregnating with zinc chlorid or steeping with bichlorid of mercury would be a suitable treatment of the cores or interiors, after which the resistant woods could be glued upon them. *The extremely poisonous character of mercuric chlorid renders its use dangerous. It is slowly volatile and there is a possibility that it will be given off continuously in small quantities from the treated wood. This matter should be carefully considered in case mercuric chlorid treatment is used for furniture and other household articles made from Kyanized wood. Coatings with heavy white lead paint might prove a safeguard.*

POISONS FOR WOOD-PULP PRODUCTS.

In the tests of insecticides for wood-pulp products, white arsenic, sodium arsenate, bichlorid of mercury, zinc chlorid, phenol (carbolic acid), copper sulphate, antimony, sodium fluorid, and creosotes were tested. The wood-pulp products in the test were various processed boards used in interior finish and as substitutes for lath, tiling, etc.

Where the board was made of four plies of fiber laminated with silicate of soda, some samples were treated on each ply before lamination, while others were treated only on the surface. These tests were made in the Tropics in cooperation with American manufacturers. For the money invested, crude carbolic acid and creosotes gave the best results, though the odor is a disadvantage. A summary of the results is given in Table 6.

Canvas finished by the cupra-ammonium process is not attacked by termites. This process consists in subjecting the fabric to the action of a solution of copper hydroxid in ammonia, whereby a compound of copper and cellulose is formed on the surface in addition to some change in the physical character of the fabric due to partial solution and reprecipitation of the cellulose. The treatment is readily removed by acids and other solvents for copper oxid and fades gradually on exposure to the weather. It has never been determined in the Bureau of Chemistry whether this fading is due to actual loss of copper or whether it is due to chemical change.

TABLE 6.—*Results of tests of wood-pulp products treated with poison to prevent attack by termites.*

Treatment.	Amount per square foot.	Amount per 1,000 square feet.	Cost per 1,000 square feet.	Condition of sample after attack of white ants.
	Ounces.			
Untreated	None.	None		Badly attacked; eaten through to silicate.
Zinc chlorid in plies		111 pounds	$1.01	Badly attacked but not eaten through to silicate.
		22½ pounds		
Zinc chlorid on surface		7 pounds	.31	Very slightly attacked.
		3 pounds	.14	Slightly attacked.
Crude carbolic acid		10 gallons	3.50	Unattacked.
		6 gallons	2.10	
		1 gallon	.35	Do.
Painted 2 coats both sides				Slightly attacked.

TABLE 6.—*Results of tests of wood-pulp products, etc.*—Continued.

Treatment.	Amount per square foot.	Amount per 1,000 square feet.	Cost per 1,000 square feet.	Condition of sample after attack of white ants.
	Ounces.			
	0.054	1.01 pounds..	$1.77	
	.043	.82 pound..	1.42	Very slightly attacked.
Bichloride of mercury on surface.	.043	.41 pound..	.72	
	.049	.46 pound..	.80	Unattacked.
	.040	.076 pound.	.13	Very badly attacked; eaten through the silicate layers on both sides.
	.045	.084 pound.	.15	
	.051	6.4 pounds..	.35	Do.
Copper sulphate on surface...	.045	5.2 pounds..	.29	
	.113	14.1 pounds.	.77	Unattacked.
	.082	10.5 pounds.	.58	
Turpentine.....	1.25	12.1 gallons..	5.06	Badly attacked; eaten through to silicate in small places on both sides.
	1.25	...do.....	5.06	
Turpentine and varnish on surface.	1.51	.....	.....	
	1.93	.....	.....	
Paraffin dipped at 132° F....	.....	71.0 pounds.	2.49	
Paraffin dipped at 150° F....	.....	62.5 pounds.	2.28	Very slightly attacked.

Results not given in some cases.

SUMMARY.

The most effective preservative in protecting timber to be set in the ground from attack by termites is coal-tar creosote. The length of service required must determine whether the method is to be a superficial treatment or a more costly but permanent impregnation.

Impregnation by the "open-tank" method with coal-tar creosote renders wood resistant to attack by termites for at least 15 years. Impregnation by the full-cell process with coal-tar creosote renders wood resistant for at least 25 years. This method is recommended for wood to be exported for use in tropical countries.

Brushing several coats of coal-tar creosote on timber will add from 2 to 5 years to its life; pigments may be added to the oil to give the wood a painted appearance.

For interior woodwork, furniture, cabinet woods, etc., impregnation with zinc chlorid, bichlorid of mercury, sodium fluorid, or chlorinated naphthalene is effective; the woods can be painted after such treatments.

Another protective method is to treat the hidden, cheaper cores of furniture, cabinet woods, etc., with preservatives during manufacture and then overlay them with veneers of termite-resistant woods.

Effective poisons to be added to wood-pulp products during manufacture are crude carbolic acid and coal-tar creosote.

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